Large Scale Diffuse X-ray Emission from the Large Magellanic Cloud

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ABSTRACT

X-ray mosaics of the Large Magellanic Cloud (LMC) taken with the *ROSAT* Position Sensitive Proportional Counter (PSPC) have revealed extensive diffuse X-ray emission, indicative of hot $\geq 10^6$ K gas associated with this irregular galaxy on scales from ~ 10 pc to ≥ 1000 pc. We have selected regions of large-scale ($d \geq 600$ pc) diffuse X-ray emission, such as supergiant shells, the LMC Spur, and the LMC Bar, and examined the physical conditions of the hot gas associated with them. We find that for these objects the plasma temperatures range from $kT \sim 0.15 - 0.60$ keV and the derived electron densities range from $n_e \sim 0.005 - 0.03$ cm^{-3}. Furthermore, we have examined the fraction of diffuse X-ray emission from the LMC and compared it to the total X-ray emission. We find that discrete sources such as X-ray binaries and supernova remnants (SNRs) account for $\sim 41\%$ and $\sim 21\%$ of the X-ray emission from the LMC, respectively. In contrast, diffuse X-ray emission from the field and from supergiant shells account for $\sim 30\%$ and $\sim 6\%$ of the total X-ray emission, respectively.

Subject headings: galaxies: ISM – Magellanic Clouds: X-rays: galaxies – X-rays: ISM

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1. Introduction

X-ray images of the Large Magellanic Cloud (LMC) produced by mosaicking pointed observations made with the *ROSAT* Position Sensitive Proportional Counter (PSPC; Snowden & Petre 1994) have revealed extensive X-ray emission associated with this irregular galaxy. The PSPC mosaic of the LMC clearly exhibits diffuse X-ray emission on scales of ~ 10 – 3000 pc, in addition to discrete point sources such as foreground stars, LMC X-ray binaries, and background active galaxies. The diffuse X-ray emission is indicative of the presence of hot ($\geq 10^6$ K) interstellar gas. This hot gas component, corresponding to the hot ionized medium (HIM) component of McKee & Ostriker's (1977) multi-phase interstellar medium (ISM), is most likely shock-heated by supernova blasts and the fast stellar winds of massive stars. Some of this diffuse X-ray emission is associated with interstellar structures such as H II regions, supernova remnants (SNRs), superbubbles, and supergiant shells, but some of the diffuse emission appears to be unbounded by any interstellar structure.

The LMC offers an ideal site to study the nature and origin of the HIM, as well as its relationship to the other phases of the ISM. At a distance of 50 kpc, the LMC is near enough so that point sources can be unambiguously distinguished from small diffuse sources, e.g., SNRs, thus a wide range of diffuse X-ray sources can be analyzed. With an inclination angle of $30° - 40°$ and a foreground extinction of $A_V \sim 0.2 - 0.8$ mag (Westerlund 1997), the LMC can be viewed with minimal confusion along the line-of-sight so that the relationship among all phases of the ISM and the underlying stellar population can be studied.

As such, much work has been performed to understand the nature and origin of the diffuse X-ray emission from the LMC on all scales. Williams et al. (1999) have recently completed an atlas of 31 SNRs in the LMC to examine the physical conditions of the 10^6 K gas on the micro-scale (~ 10 pc). Dunne, Points, & Chu (2001) have examined the physical conditions of the hot gas interior to a sample of 13 X-ray bright superbubbles on the meso-scale (~ 100 pc). This paper addresses the physical properties of the $\geq 10^6$ K on the macro-scale (~ 1000 pc).

This paper is organized as follows: Section 2 describes the observations used in this study and their reduction. The distribution of the hot ($\geq 10^6$ K) plasma and its relationship to the warm ($\sim 10^4$ K) gas on a global scale and for individual objects is discussed in §3. In §4 we determine the physical conditions of the $\geq 10^6$ K gas. We summarize our results in §5.

2. Observations and Data Reduction

The X-ray mosaics of the LMC were obtained with the *ROSAT* X-ray telescope, using the PSPC which has a 2° diameter field-of-view. The data were retrieved through the *ROSAT* public archive[2] at the High Energy Astrophysics Science Archive Research Center (HEASARC) at NASA's Goddard Space Flight Center. Table 1 lists the observation sequences that were used for the PSPC mosaics. The table includes the number of data sets for each sequence (the observation of individual targets was often broken into multiple segments, some of which required separate processing), pointing direction, exposure time, and target name. The data reduction was accomplished using the Extended Source Analysis Software (ESAS) package[3] (Snowden & Kuntz 1998; Kuntz & Snowden 1998), which is also available through the HEASARC. The final PSPC mosaics are cast in the zenith equal-area azimuthal (ZEA; Greisen & Calabretta 1996) projection, which is similar over this solid angle to tangential projection. This projection has a field center of $\alpha_{2000} = 5^{\rm h}28^{\rm m}$, $\delta_{2000} = -67°15'$, a pixel size of $40''$, and covers 51.27 square degrees. We present the PSPC mosaic of the LMC in the R4 to R7 (0.44 – 2.04 keV; see Table 2) energy band and the exposure map for the R5 energy band (0.56 – 1.21 keV) in Figures 1 and 2, respectively.

Reduction of the PSPC data followed the procedures outlined by Snowden et al. (1994) and demonstrated by Snowden & Petre (1994). In fact, the PSPC mosaic presented in Figure 1 includes a reprocessing of data presented by Snowden & Petre (1994). This new mosaic was made from 129 pointed PSPC observations, whereas the previous mosaic was made from ~ 40 pointed PSPC observations. The individual observations were screened for anomalous background conditions, had their residual non-cosmic background components modeled and subtracted, and had their vignetted and deadtime-corrected exposures calculated. Only after all of the individual observations were reduced in six statistically-independent energy bands (see Table 2) were they cast into the mosaics. Because the analysis software cannot correct for zero-level offsets (a constant component of the long-term enhancement in the non-cosmic background, see Snowden et al. 1994), the mosaicking process must correct for the relative offsets between overlapping fields. A single-value deconvolution algorithm was applied to a system of equations comprising the count rates for all overlaps between separate observations to determine a best fit for all offsets simultaneously. A final constraint was added so that the sum of the offsets were equal to zero. Individual observations were then adjusted by multiplying the fitted offset by the exposure map to produce an offset count image, which was then subtracted from the count image. This procedure was run separately for each energy

[2]http://heasarc.gsfc.nasa.gov/W3Browse/

[3]ftp://legacy.gsfc.nasa.gov/rosat/software/fortran/sxrb/

band. Table 3 lists the average exposure time, the total counts, the total background counts, and the average intensity of each band. The true source counts can be seen to completely dominate the non-cosmic background and the average exposures are larger by more than an order of magnitude than that of the *ROSAT* All Sky Survey coverage.

3. Distribution of the Large Scale Diffuse X-ray Emission

In this section we first describe the global distribution of the diffuse X-ray emission toward the LMC and compare it with the spatial distribution of 10^4 K ionized gas in the LMC. Based upon the X-ray images, we show that the X-ray emission most likely has a hot $\geq 10^6$ K origin. From these images, we select regions of large scale diffuse X-ray emission that have, in most cases, optical counterparts. Finally, we examine the relationship between the hot and the warm ionized gas for the individual structures.

3.1. Global Distribution of the X-ray Emitting Plasma

As seen in Figure 1, the LMC clearly exhibits extensive diffuse emission in the R4 to R7 energy band. The diffuse X-ray emission in the LMC occurs on physical scales from ~ 10 pc to > 1000 pc. Observations of the LMC with the *ROSAT* High Resolution Imager (HRI) do not show evidence that the large scale diffuse X-ray emission is produced by a population of point sources that were unresolved by the PSPC, indicating a hot ($\geq 10^6$ K) gas origin (Chu & Snowden 1998). The X-ray surface brightness of the large-scale diffuse X-ray emission is non-uniform across the LMC. It varies from $\sim 3.5 \times 10^{-4}$ counts s^{-1} arcmin^{-2} in the northwest to $\sim 4.0 \times 10^{-3}$ counts s^{-1} arcmin^{-2} in the southeast in the R4 to R7 band. This range of X-ray surface brightness is comparable to that measured for LMC superbubbles (*cf.* Dunne et al. 2001), but is a factor of ~ 100 lower than that of LMC SNRs (*cf.* Williams et al. 1999). The large scale diffuse X-ray emission most likely originates in the LMC because it has a higher surface brightness than the nominal off-LMC value of $\sim 2.5 \times 10^{-4}$ counts s^{-1} arcmin^{-2} in the R4 to R7 band mosaic (Snowden & Petre 1994; Snowden 1999).

We have compared the PSPC X-ray mosaic of the LMC with the Hα Sky Survey image (Gaustad et al. 1999) of the LMC (Figure 3) to identify the 10^4 K ionized gas counterparts, if any, of the large scale diffuse X-ray emission. As can be seen by comparing Figures 1 and 3, some of the large scale diffuse X-ray emission is associated with LMC supergiant shells (e.g., LMC 2), further suggesting a hot gas origin. Some of the diffuse X-ray emission, however, appears to be unbounded by any interstellar structure (e.g., the Spur and the LMC Bar).

The regions of large scale diffuse X-ray emission toward the LMC that we have selected for study, as well as their positions, physical sizes, and the measured Galactic and LMC H I column densities, $N_{\rm H\,I}^{\rm Gal}$ and $N_{\rm H\,I}^{\rm LMC}$, respectively, toward them are presented in Table 4. The designations of the regions of large scale diffuse X-ray emission presented in Table 4 are taken to correspond with names given to their optical counterparts, where appropriate.

3.2. Individual Objects

Below we describe the spatial distribution of the 10^4 K gas and compare it with the distribution of the $\geq 10^6$ K gas for the regions of large scale diffuse X-ray emission listed in Table 4. We first discuss the distribution of the 10^4 K ionized gas and then the $\geq 10^6$ K gas of the selected regions because it is often useful to use the optical features as a reference for the X-ray emission.

The Hα images of the regions have been extracted from the PDS scans of the Curtis Schmidt plates of Kennicutt & Hodge (1986). The two exceptions for this are (1) LMC 1, which is not covered by the PDS scans, and (2) the LMC Bar region, which covers more than one PDS scan field-of-view. For LMC 1, the Hα image has been mosaicked from images obtained by the Magellanic Cloud Emission-line Survey (MCELS; Smith et al. 1999). For the LMC Bar, the image has been extracted from the Hα Sky Survey (Gaustad et al. 1999) image of the LMC. The X-ray images for the individual objects have been extracted from the PSPC mosaic of the LMC (Figure 1).

We present the Hα and PSPC X-ray images of the individual objects in Figures 4 – 12. The gray-scale levels among the images are not the same so that the objects with lower X-ray and Hα surface brightness can be seen more clearly. To aid in the comparison between the 10^4 K and 10^6 K gas for each object we have plotted X-ray contours at the 3, 5, 10, 15, and 20-σ level above the local background. Because the selected regions cover a large spatial extent, smaller scale X-ray sources (e.g., X-ray binaries, SNRs, and superbubbles) also lie projected along the line-of-sight. Therefore, we have also plotted additional contour levels at 50, 100, 150, and 200-σ level above the mean local background. These contours are plotted as dashed lines. Small-scale features mentioned in the text such as H II regions, SNRs, and superbubbles have also been labeled.

3.2.1. LMC 1

The Hα image of LMC 1 (Figure 4 a) shows a very coherent shell structure with a diameter of $\sim$ 700 pc. The northern and eastern filaments of LMC 1 are better defined than the filaments in the west and south. A single H II region (N 13) lies projected toward the southeastern side of LMC 1. Diffuse X-ray emission is detected interior to the Hα filaments defining LMC 1.

The diffuse X-ray emission from within LMC 1 seems to fill the shell in the area covered by the PSPC mosaic (Figure 4 b). The diffuse X-ray emission from within LMC 1 peaks in the western portion of the shell and along the southern rim. Some of the diffuse X-ray emission extends beyond the ionized filaments in the southwest, suggesting a blowout of the hot gas. High resolution H I aperture synthesis images of LMC 1 (Kim et al. 1999) show H I filaments extending beyond the X-ray emission region, indicating that the hot gas is confined by the H I gas.

3.2.2. LMC 2

The distribution of 10^4 K ionized gas toward LMC 2 is revealed in the Hα image (see Figure 5 a). This image shows long filaments in the north and the east and shorter filaments in the south. Together, these filaments suggest a coherent shell structure with a diameter of $\sim$ 900 pc. LMC 2 is bordered on its western edge by the most active star formation complex in the LMC: N 157 (30 Doradus), N 158, N 160, and N 159. In addition to this ridge of star formation, many other H II regions lie along the periphery or are projected interior to LMC 2. Two SNRs are projected near the periphery of LMC 2: DEM L 299 at the northern border and DEM L 316 in the southeast (Mathewson et al. 1983; Williams et al. 1997). Diffuse X-ray emission is detected interior to the ionized filaments that define the boundary of LMC 2.

The spatial distribution of X-ray emission and the physical properties of the hot gas toward LMC 2 have been extensively studied (Wang & Helfand 1991; Points et al. 1999; Points et al. 2000); therefore, we summarize those results here. LMC 2 has the highest X-ray surface brightness of all the supergiant shells in the LMC; the peak of the diffuse emission is approximately 35 times higher than the off-LMC background. The diffuse X-ray emission from within LMC 2 is confined by the filaments to the north and east, but extends beyond the southern filaments in a bright X-ray Spur (see Figure 11 and §3.2.8). The diffuse X-ray emission toward LMC 2 is non-uniform. A bright X-ray arc is seen in the southwest that appears to extend from N 158 to N 159, centered on N 160. A region of lower X-ray surface brightness lies between the X-ray arc and a region of bright emission in the northeast. The bright X-ray arc in the southwest has been suggested as a blowout of hot gas from N 160 into LMC 2. The region of low X-ray surface brightness ($\alpha_{2000} = 5^{\rm h}45^{\rm m}$, $\delta_{2000} = -69°25'$) is likely caused by absorption from an H I cloud on the front side of LMC 2. The bright northern region is probably energized by an SNR shock interior to LMC 2 hitting the shell wall. As seen in Figure 5 b, discrete X-ray emission sources are located toward LMC 2. These sources include 30 Doradus, SNRs (i.e., SNR 0540−69.3, DEM L 299, & DEM L 316) and a high mass X-ray binary (i.e., LMC X-1).

3.2.3. LMC 3

The Hα image of LMC 3 (Figure 6 a) shows an intricate filamentary shell structure to the northwest of the 30 Doradus star formation complex with a diameter $\sim$ 1000 pc. The ionized filaments do not have the coherence of those seen in LMC 1 and LMC 2, but are suggestive of a complete shell structure. Several H II regions lie along the periphery of LMC 3 and appear to be connected by the ionized filaments. Diffuse X-ray emission is detected toward LMC 3.

The diffuse X-ray emission toward LMC 3 covers the interior of the supergiant shell (see Figure 6 b). The X-ray surface brightness of the diffuse emission is non-uniform. The diffuse X-ray emission peaks along the eastern rim of LMC 3. Several local depressions in the X-ray surface brightness are also seen in the PSPC mosaic toward LMC 3. Two of these minima are coincident with H II regions projected toward LMC 3: N 148 (DEM L 227) along the northern rim and DEM L 210 toward the center. These two depressions are more pronounced in the R4+R5 energy band than in the R6+R7 energy band, indicative of absorption. Therefore, it is likely that N 148 and DEM L 210 lie on the front side of LMC 3. In addition to the large scale diffuse X-ray emission associated with LMC 3, discrete X-ray sources such as foreground stars, SNRs (e.g., SNR 0528−692), and superbubbles (e.g., N 144) are seen in Figure 6 b.

3.2.4. LMC 4

LMC 4 is the largest optically identified supergiant shell in the LMC with a dimension of 1400 pc $\times$ 1000 pc. LMC 4 consists of fragmented ionized gas filaments that seem to connect the numerous H II regions along its periphery, suggesting a coherent shell structure (Figure 7 a). Diffuse X-ray emission is detected within LMC 4.

The physical conditions of the hot ($\geq 10^6$ K) gas interior to LMC 4 have been reported by Bomans, Dennerl, & Kürster (1994). The PSPC mosaic of LMC 4 (Figure 7 b) shows very low surface brightness emission. LMC 4 has a a low foreground H I column density of $N_{\rm H\,I} = 1.26 - 1.84 \times 10^{21}$ cm^{-2}. Therefore, the absence of strong X-ray emission detected toward LMC 4 is not caused by absorption. In general, the X-ray emission from the interior of LMC 4 appears limb-brightened, but the brightest diffuse X-ray emission in the west and south rims is only a factor of ~ 2 brighter than the X-ray emission from the center of the supergiant shell. The X-ray emission from the western side of LMC 4 is not associated with any Hα emission features and is probably gas interior to LMC 4. The diffuse X-ray emission detected toward the southern boundary of LMC 4, however, is more confusing. This emission is most likely associated with the superbubbles that border LMC 4 along the southern rim, such as N 51 and N 57. Discrete X-ray sources, such as an X-ray binary (i.e., LMC X-4), and SNRs (i.e., N 49, N 49 B, DEM L 241, & N 63 A) are also seen in the PSPC mosaic image.

3.2.5. LMC 5

The Hα image of LMC 5 (Figure 8 a) shows faint, irregular ionized filaments with a diameter of ~ 800 pc to the northwest of LMC 4. A long ionized filament (~ 300 pc long) appears to bisect the LMC 5, giving the impression that LMC 5 is comprised of two distinct shells.

The diffuse X-ray emission from LMC 5 covers most of its interior (see Figure 8 b). The brightest diffuse X-ray emission from LMC 5 is located to the south of the Hα filament that divides the shell. The bright diffuse X-ray emission at the south rim cannot be unambiguously associated with LMC 5, however, because it lies projected toward an H II region (N 48). A region of lower X-ray surface brightness is seen along the western rim of the shell, coincident with the Hα filaments. The lowered X-ray surface brightness may be the result of the ionized gas absorbing the X-ray emission from inside the supergiant shell. The strong X-ray sources to the east of LMC 5 are the SNRs, N 49 and N 49 B. The X-ray sources to the west of the LMC 5 are two foreground Galactic late-type stars.

3.2.6. LMC 6

The warm ionized shell of LMC 6 is very faint and circular in appearance, with a diameter of ~ 600 pc (see Figure 9 a). It is the smallest supergiant shell in the LMC (Meaburn 1980). The surface brightness of the ionized filaments is highest toward the H II regions N 91 and N 92 along the northern and southern boundaries, respectively. In addition to these H II regions, the SNR N 86 is projected on the western rim of LMC 6.

The spatial distribution of the X-ray emitting plasma from LMC 6 appears limb-brightened (see Figure 9 b). LMC 6 has a very low X-ray surface brightness, $\lesssim 2$ times the off-LMC background. The peak diffuse X-ray emission toward LMC 6 lies toward N 91 and may be associated with the H II region. The bright, discrete X-ray sources toward LMC 6 are the N 86 SNR and a late-type Galactic star.

3.2.7. LMC 10 (DEM L 268)

The large scale structure designated as LMC 10 was tentatively identified as a supergiant shell candidate by Meaburn (1980). These faint ionized filaments lie to the north of 30 Doradus and LMC 3 (Figure 10 a). The Hα morphology of the LMC 10 show the filaments to be pointing away from 30 Doradus and LMC 3, particularly in the area toward N 148 along the northeastern rim of LMC 3.

The PSPC mosaic of LMC 10 (Figure 10 b) shows an arc of X-ray emission that stretches from the northern edge of LMC 3 and may continue toward the southern edge of LMC 4. The X-ray emission from this arc has a fairly high surface brightness, with a peak approximately 5 times the off-LMC background. The extent of the X-ray emission of LMC 10 cannot be measured in our PSPC images because of incomplete coverage of the mosaic toward its central region.

3.2.8. LMC Spur

The X-ray Spur in the LMC lies to the south of the supergiant shell LMC 2 (see Figure 1). The Hα image of the Spur (Figure 11 a) shows several H II along its western edge, but does not reveal any 10^4 K ionized filaments encompassing it. Thus, its boundaries and physical size are defined solely from the PSPC mosaic. Even though little 10^4 K ionized gas is detected toward the Spur, other phases of the ISM are present. Observations of the ^{12}CO $J = 1 \rightarrow 0$ emission line at 2.6 mm made with the NANTEN 4-m radio telescope (Fukui et al. 1999) reveal that the Spur is bordered on the west by a ridge of molecular gas. The H II regions along the western edge are superposed on this molecular ridge.

The PSPC mosaic image (Figure 11 b) reveals that the Spur has a physical size of $\sim$ 900 pc, comparable to LMC 2. The Spur has the second highest average X-ray surface brightness of all the objects in this study. It has been suggested that the Spur represents a blowout of the hot gas interior to LMC 2 into the halo of the LMC (Wang & Helfand 1991) although high-resolution optical spectra toward the Spur do not reveal any high-velocity gas that would be indicative of an outflow (Points et al. 1999). Very little structure or variation in the X-ray surface brightness is observed toward the Spur. This is remarkable because LMC 2 shows X-ray surface brightness variations on smaller scales that are caused by differential absorption (Points et al. 1999; Points et al. 2000). The smooth distribution of X-ray emission from the Spur may imply a very uniform foreground absorption. The western boundary of the Spur is coincident with the ridge of molecular gas. This molecular material could be absorbing X-ray emission from the Spur and be responsible for the sharp western edge of the X-ray emission.

3.2.9. LMC Bar

The LMC Bar primarily consists of an intermediate-age stellar population upon which many H II regions are superposed (see Figure 12 a) such as N 113, N 114, N 119, and N 120. The X-ray bar of the LMC is the largest region of diffuse X-ray emission reported here with a major axis $\sim$ 3000 pc and a minor axis $\sim$ 1000 pc.

The PSPC mosaic (Figure 12 b) shows bright large-scale diffuse gas from the bar region of the LMC. The HRI survey of the LMC (Chu & Snowden 1998) does not show large population of point sources that are unresolved by the PSPC. We note, however, that the *ROSAT* HRI survey of the LMC has a detection limit of $\sim 1 \times 10^{34}$ erg s^{-1} for point sources (Chu & Snowden 1998). Thus, some of the X-ray emission from the LMC Bar could consist of point sources that were unresolved by the PSPC, but not detected by the HRI because of its high background. If the X-ray emission from the LMC Bar is produced by coronal emission from unresolved late-type stars in the LMC Bar, the stellar density of this population would be $\sim$ 120 pc^{-3}, which is unrealistically high. Therefore, the X-ray emission from the LMC Bar appears to be truly diffuse. In general, the X-ray emission is not spatially correlated with the star forming regions superposed on the LMC Bar. Discrete X-ray sources such as SNRs (e.g., SNR 0519−690, SNR 0520−694, N,120, and N 132 D) and foreground stars are seen projected toward the LMC Bar.

4. Discussion

4.1. Physical Properties of the Hot Gas

Before the physical conditions of the $\geq 10^6$ K gas can be determined, we must first excise the discrete X-ray emission sources, such as foreground Galactic stars, LMC X-ray binaries, SNRs, and superbubbles, and background active galactic nuclei, from all of the PSPC mosaic band images. For this purpose, we used the catalog of *ROSAT* PSPC X-ray sources toward the LMC that was compiled by Haberl & Pietsch (1999) to obtain the positions of the discrete sources. After the contaminating sources were removed from the mosaics, the background-subtracted PSPC count rates are determined for the regions of large scale diffuse X-ray emission in each PSPC band. The count rates in the individual bands were then summed to obtain count rates in the R4 + R5 (0.44 – 1.21 keV) and R6 + R7 (0.73 – 2.04 keV) energy bands. The angular size of the extraction regions, net source count rates in the PSPC energy bands and the $\frac{(\mathrm{R6+R7})}{(\mathrm{R4+R5})}$ ratio for the regions of large scale diffuse X-ray emission are presented in Table 5.

The measured X-ray surface brightness of the hot gas is dependent upon the temperature of the thermal plasma and the foreground absorption. If the foreground absorption can be independently measured, the intensity ratio between the different bands can be used to determine the temperature of the emitting gas. We use a Raymond & Smith (1977) thermal plasma emission model with 40% solar abundance[4] to interpret the $\frac{(\mathrm{R6+R7})}{(\mathrm{R4+R5})}$ band intensity ratios of the selected regions as an effective temperature of the hot plasma associated with them. We use measurements of the Galactic and LMC H I column densities from the data presented by Dickey & Lockman (1990) and Rohlfs et al. (1984) respectively, to determine lower and upper limits on the total foreground absorption column to the regions of interest in the LMC. As seen in Table 4, the Galactic H I column density, $N_{\mathrm{H\,I}}^{\mathrm{Gal}}$, ranges from $\sim 4-7 \times 10^{20}$ cm^{-2}. Arabadjis & Bregman (1999) have shown that for column densities $N_{\mathrm{H}} > 5 \times 10^{20}$ cm^{-2}, the total X-ray absorption column is nearly double the H I column density because of the contribution of molecular gas. Although molecular gas does contribute to the total absorption column above column densities $\sim 5 \times 10^{20}$ cm^{-2}, it is neither a factor of 2 uniformly over the sky, nor a step function at 5×10^{20} cm^{-2}. Thus, the contribution to the total absorption column by the Galactic ISM probably ranges from 1 to 2 times $N_{\mathrm{H\,I}}^{\mathrm{Gal}}$. Continuing this approximation to the LMC absorption column is more difficult. Measurements of the LMC H I column density sample material that is both in front of and behind the regions of interest. We use the simplifying assumption that half of the neutral atomic gas is foreground to the regions and that half is background. Thus, the LMC component of the total absorption column density is $\frac{1}{2} \times 2N_{\mathrm{H\,I}}^{\mathrm{LMC}} = N_{\mathrm{H\,I}}^{\mathrm{LMC}}$. The total absorption column is between $N_{\mathrm{H\,I}}^{\mathrm{Gal}} + N_{\mathrm{H\,I}}^{\mathrm{LMC}}$ and $2N_{\mathrm{H\,I}}^{\mathrm{Gal}} + N_{\mathrm{H\,I}}^{\mathrm{LMC}}$. We use both of these limiting values of the foreground absorption to determine the physical conditions of the $\geq 10^6$ K gas in the regions of interest. Figure 13 shows a plot of the PSPC $\frac{(\mathrm{R6+R7})}{(\mathrm{R4+R5})}$ band ratio versus N_{H} for a set of 40% solar abundance Raymond & Smith (1977) plasma emission models with

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[4]We discuss our selection of 40% solar abundance plasma emission models below.

temperatures ranging from $\mathrm{Log}(\frac{\mathrm{T}}{\mathrm{K}}) = 6.2 - 6.9$ (or $kT = 0.14 - 0.68$ keV). For the selected regions of large scale diffuse X-ray emission in the LMC, the plasma temperature varies from $kT \sim 0.16 - 0.60$ keV. As seen in Figure 13, the errors in the $\frac{\mathrm{(R6+R7)}}{\mathrm{(R4+R5)}}$ band ratios imply that the supergiant shell LMC 2 could have a plasma temperature ranging from $kT = 0.22$ to 0.68 keV if the foreground absorption is 4.4×10^{21} cm^{-2} for a Raymond & Smith (1977) 40% solar abundance plasma emission model. This range in plasma temperature for the hot gas interior to LMC 2 is similar to the 90% confidence limits on the plasma temperature that were determined by thermal plasma model fits to *ROSAT* PSPC spectra of LMC 2 (Points et al. 2000).

From the determination of the plasma temperatures and the measured foreground absorption, we use PIMMS[5] (Mukai 1993) to calculate the unabsorbed X-ray fluxes, and hence X-ray luminosities, of the regions in the R4 to R7 energy band. Given a hot gas filling factor, f, volume, V, X-ray luminosity, L_X, and emissivity, Λ, the electron density of the hot plasma will be

$$n_e = (1.1 L_X)^{1/2} (\Lambda V f)^{1/2},$$

if $n_e = 1.1 n_{\mathrm{H}}$. For the selected regions, we assume that the volume of the gas is equal to the product of the surface area and the path length through the gas. We adopt a path length comparable to the width of the region in question. We derive the electron densities for the large scale diffuse X-ray emission regions using the calculated X-ray luminosities and emissivities and present them in Table 6. The average electron densities in these regions varies from ~ 0.004 cm^{-3} in LMC 4 to ~ 0.03 cm^{-3} in the LMC Spur.

The preceding derivation of the physical conditions of the hot gas associated with the large scale diffuse X-ray emission in the LMC is not without its caveats. The major uncertainties in our calculations do not arise from uncertainties in the measured count rates, but are attributed to the assumptions we have made concerning the metallicity of the X-ray emitting gas, the geometry of the emitting region and the foreground absorption. For example, the canonical chemical abundance of the ISM in the LMC is 30% of the solar value (Russell & Dopita 1992). In this work, however, we have determined the physical conditions of the hot gas using a Raymond & Smith (1977) thermal plasma with 40% solar abundance because PIMMS does not have a grid of 30% solar abundance Raymond & Smith (1977) models. Therefore, we have calculated the plasma temperatures, X-ray luminosities, and electron densities of the selected regions using a Raymond & Smith (1977) thermal plasma with 20% solar abundance to investigate the importance of the chemical abundance on the physical conditions of the hot gas. This work shows that the mean percent difference in

[5]http://heasarc.gsfc.nasa.gov/docs/software/tools/pimms.html

plasma temperatures between Raymond & Smith (1977) models with 20% and 40% solar abundances is $\sim$ 4% for the individual objects, but that the mean percent differences in the X-ray fluxes and electron densities are $\sim$ 33% and $\sim$ 20%, respectively. Another complicating factor in calculating the physical properties of the 10^6 K gas is the uncertainty in the three dimensional geometry, or volume, of the individual regions. Therefore, we simply take the volume to be the product of the projected surface area and the path length through the gas where the path length is equal to the width of the structure. Because the depth through these structures is uncertain, an increase (decrease) of the path length, l, by a factor of two, would decrease (increase) our determination of the electron density by a factor of $\sqrt{2}$. The final assumption that we have made is that the foreground absorption column toward the individual regions of interest is uniform and can be represented as a combination of the Galactic and LMC H I column densities. We have shown in §3.2 that some of the fluctuations in the X-ray surface brightness toward the individual objects are associated with differential absorption. Therefore, the assumption of uniform absorption across each region is clearly not correct if we want to investigate the variations in plasma temperature and electron density across each region of interest. Thus, we only can determine the average physical conditions of the hot gas in the regions.

4.2. Fraction of Diffuse Emission to Total Emission

In addition to determining the physical properties of the $\geq 10^6$ K gas in our sample of selected objects, we have also investigated the contribution of these objects to the total X-ray emission observed from the LMC. This comparison will allow us to better understand the X-ray emission from more distant Magellanic Irregular galaxies with star formation rates of 0.26 $M_\odot$ yr^{-1} (Kennicutt et al. 1995). As previously discussed, the X-ray emission from the PSPC mosaics is comprised of emission from: (1) AGN and background galaxies, (2) foreground stars, (3) the soft X-ray background, and (4) LMC sources (e.g., X-ray binaries, SNRs, superbubbles, supergiant shells, and field emission). Therefore, in order to determine the amount of X-ray emission that is intrinsic to the LMC, we must determine and subtract the contributions of the background galaxies, foreground stars, and the soft X-ray background from the PSPC mosaic. Below we discuss the removal of these different sources from PSPC mosaics and determine the X-ray emission that is attributed to sources in the LMC.

The first step in calculating the diffuse X-ray emission from the LMC is determining the soft X-ray background toward the LMC in the R1 to R7 (0.1 – 2.04 keV) energy band and subtracting it from the PSPC mosaics. To determine the soft X-ray background in this energy range we have created two broadband X-ray images of the LMC: the first in the

R4 to R7 (0.44 – 2.04 keV) energy band (see Figure 1) and the second in the R1 to R2 (0.1 – 0.28 keV) energy band (see Figure 1 of Snowden 1999). The off-LMC background in the R4 to R7 band has been previously measured by Snowden & Petre (1994) to be $\sim 2.5 \times 10^{-4}$ counts s^{-1} arcmin^{-2}. Unfortunately, there are no published values of the off-LMC background in the R1 to R2 band; therefore, we need to measure the value of the background directly from the R1 to R2 mosaic of the LMC. To accomplish this task, we have determined the mean count rate in 10 regions, each having an angular extent of 10 arcmin^2, along the periphery of the R4 to R7 PSPC mosaic. The average background measured in these 10 regions is $\sim 2.4 \times 10^{-4}$ counts s^{-1} arcmin^{-2}, in good agreement with the value reported by Snowden & Petre (1994). Somewhat confident that these 10 regions are representative of the off-LMC background in the R4 to R7 band, we use them to determine the off-LMC background to be $\sim 4.2 \times 10^{-4}$ counts s^{-1} arcmin^{-2} in the R1 to R2 band[6]. After the off-LMC backgrounds in the R4 to R7 and R1 to R2 energy bands are subtracted, we combine the resulting images to make a mosaic of the LMC in the R1 to R7 energy band.

Now that the background has been subtracted from the PSPC mosaic in the R1 to R7 energy band, we use the list of X-ray sources toward the LMC compiled by Haberl & Pietsch (1999) to determine the contribution of discrete, point-like sources (e.g., AGN, foreground stars, X-ray binaries, supersoft X-ray sources, SNRs, and unclassified X-ray sources) to the total emission in the PSPC mosaics. We have also taken the list of superbubbles in the LMC compiled by Dunne et al. (2001) and the list of large scale structures discussed in §3 to determine their contribution to the total emission in the PSPC mosaic. After the contributions from all of these sources are subtracted from the total X-ray emission in the background-subtracted PSPC mosaic, we are left with the diffuse X-ray emission from the field of the LMC. We present these results in Table 7. As seen in Table 7, the largest contribution to the X-ray emission from the LMC comes from X-ray binaries and supersoft X-ray sources (41%). Surprisingly, the second largest contribution to X-ray emission from the LMC is from diffuse gas in the field (29%). This is slightly higher than the X-ray emission produced by SNRs (21% of the total) and three times the amount of X-ray emission associated with supergiant shells, the Spur and the Bar. Diffuse X-ray emission from superbubbles makes a small contribution to the total X-ray emission from the LMC (2%).

As with any calculation, we must consider the factors that produce uncertainties. The

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[6]The soft X-ray background in the R1 to R2 energy band has been measured to be $\sim 1.04 \times 10^{-3}$ counts s^{-1} arcmin^{-2} toward the north Galactic Pole (Kuntz & Snowden 2000). Snowden et al. (1998) note that the soft X-ray emission in the northern hemisphere is ~ 2 times stronger than in the southern hemisphere in this energy range. The value we determined for the background in the R1 to R2 band is within 20% of the expected background of $\sim 5 \times 10^{-4}$ counts s^{-1} arcmin^{-2}.

largest source of error in the determination of of total X-ray emission from the LMC, and hence the emission from diffuse gas in the field is the value of the off-LMC X-ray background in the R1 to R2 energy band. If the off-LMC background in the R1 to R2 band is one half of the X-ray background in the R1 to R2 band observed toward the north Galactic Pole (see Kuntz & Snowden 2000), then the contribution of diffuse X-ray emission from the field to the total X-ray emission from the LMC drops from 27% to 20% of the total. This is primarily a consequence of the method by which we determined the amount of diffuse X-ray emission from the field. To determine the count rate for the field emission we subtracted the emission from the cataloged sources from the total emission in the background-subtracted PSPC mosaic. We attribute the difference between the total X-ray emission in the LMC and the cataloged sources to be from diffuse gas in the field. Thus, by increasing the soft X-ray background in the R1 to R2 energy band, we decrease the total number of counts in the PSPC mosaic, effectively reducing the amount of diffuse X-ray emission from the field. Another source of potential error in the determination of the amount of X-ray emission intrinsic to the LMC is errors in the count rates we determined from the PSPC mosaics for the cataloged superbubbles in the LMC (*cf.*, Dunne et al. 2001) and the objects listed in §3. To check the accuracy of our source extraction from the mosaics, we have also determined the count rates of the cataloged SNRs and X-ray binaries in the LMC and compared these values with those determined by Haberl & Pietsch (1999). The total count rates that we determined for SNRs and X-ray binaries are within 5% of those determined by Haberl & Pietsch (1999). Therefore, we conclude that our method of extracting source counts directly from the PSPC mosaics does not significantly affect our determination of the total X-ray emission from the LMC and that the largest source of error lies in the determination of the off-LMC background. Finally, there is also considerable uncertainty due to the foreground absorption to the LMC. The Galactic H I column densities toward the LMC are $\sim 6 \times 10^{20}$ cm^{-2}, corresponding to $4 - 5$ optical depths at $\frac{1}{4}$ keV. Thus, small errors in the assumed foreground absorption can have large effects on the determined PSPC count rates.

5. Summary

The PSPC mosaics of the LMC provide an unprecedented and detailed global view of the $\geq 10^6$ K gas in a galaxy. The diffuse X-ray emission is non-uniform across LMC and shows a highly complex ISM with features on the scale from a few arcminutes to over several degrees. Furthermore, these X-ray mosaics allow us to examine the spatial distribution and physical conditions of diffuse X-ray emission on scales larger than a single pointed PSPC observation allows.

We have selected regions of large-scale X-ray emission in the LMC and compared them with Hα images. This comparison shows that while some of the large scale diffuse X-ray emission is associated with supergiant shells, some is also unbounded such as the LMC Spur, and the LMC bar. We have determined the physical properties of these regions of large scale diffuse emission. We find that the plasma temperature varies from ~ 0.2 to ~ 0.6 keV and the X-ray surface brightness varies from ~ 0.07 – $\sim 5 \times 10^{-14}$ erg cm^{-2} s^{-1} arcmin^{-2}. The electron density of the hot gas in these regions varies from 0.003 cm^{-3} to 0.030 cm^{-3}.

We have determined the X-ray count rate from the LMC in the R1 to R7 energy band. Discrete sources, such as foreground stars, AGN, X-ray binaries, SNRs, and superbubbles, were removed. From this we are able to determine the X-ray count rate from the selected regions and from the field. We find that X-ray emission from the field of the LMC contributes between 20% to 27% of the total X-ray emission from the LMC, depending on how the X-ray background is removed. The diffuse X-ray emission from the field provides a significant contribution to the total X-ray luminosity of the LMC. It is comparable to the amount of X-ray emission associated with SNRs in the LMC and is a factor of 2 to 3 times greater than the X-ray emission associated with supergiant shells, the Spur, and the Bar in the LMC.

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Fig. 1.— *ROSAT* PSPC mosaic of the LMC in the R4 to R7 (0.44 – 2.04 keV) energy band. Darker regions indicate higher intensity. The image has been logarithmic scaled with an intensity range that saturates at 5×10^{-3} counts s^{-1} $arcmin^{-2}$. The regions discussed in §3.2 are marked. The bar in the upper left corner indicates a length 500 pc, assuming a distance of 50 kpc to the LMC.

Fig. 2.— Gray-scale map of the R5 (0.56 – 1.21 keV) energy band exposure. Darker regions indicate higher exposure. The image has been logarithmic scaled with an intensity range that saturates at 100 ksec.

Fig. 3.— Hα Sky Survey image of the LMC (Gaustad et al. 1999). The image has been sky- and continuum-subtracted. The white "holes" are an artifact of the continuum subtraction. The image has been logarithmic scaled and covers the same region as Figure 1. The individual regions discussed in §3.2 are marked. The bar in the upper left corner indicates a length 500 pc, assuming a distance of 50 kpc to the LMC.

Fig. 4.— **(a)** MCELS Hα image of LMC 1. **(b)** *ROSAT* PSPC image of LMC 1 in the R4 – R7 (0.44 – 2.04 keV) energy band. **(c)** and **(d)** The same as **(a)** and **(b)** with X-ray contours overlaid. The solid contours in **(c)** and **(d)** are 3, 5, 10, 15, and 20-σ above the mean local background. The dashed contours are 50, 100, 150, and 200-σ above the mean local background.

Fig. 5.— **(a)** Curtis-Schmidt Hα PDS scan of LMC 2 (Courtesy R. Kennicutt). **(b)** *ROSAT* PSPC image of LMC 2 in the R4 – R7 (0.44 – 2.04 keV) energy band. **(c)** and **(d)** The same as **(a)** and **(b)** with X-ray contours overlaid. The solid contours in **(c)** and **(d)** are 3, 5, 10, 15, and 20-σ above the mean local background. The dashed contours are 50, 100, 150, and 200-σ above the mean local background.

Fig. 6.— **(a)** Curtis-Schmidt Hα PDS scan of LMC 3 (Courtesy R. Kennicutt). **(b)** *ROSAT* PSPC image of LMC 3in the R4 – R7 (0.44 – 2.04 keV) energy band. **(c)** and **(d)** The same as **(a)** and **(b)** with X-ray contours overlaid. The solid contours in **(c)** and **(d)** are 3, 5, 10, 15, and 20-σ above the mean local background. The dashed contours are 50, 100, 150, and 200-σ above the mean local background.

Fig. 7.— **(a)** Curtis-Schmidt Hα PDS scan of LMC 4 (Courtesy R. Kennicutt). **(b)** *ROSAT* PSPC image of LMC 4 in the R4 – R7 (0.44 – 2.04 keV) energy band. **(c)** and **(d)** The same as **(a)** and **(b)** with X-ray contours overlaid. The solid contours in **(c)** and **(d)** are 3, 5, 10, 15, and 20-σ above the mean local background. The dashed contours are 50, 100, 150, and 200-σ above the mean local background.

Fig. 8.— **(a)** Curtis-Schmidt Hα PDS scan of LMC 5 (Courtesy R. Kennicutt). **(b)** *ROSAT* PSPC image of LMC 5 in the R4 – R7 (0.44 – 2.04 keV) energy band. **(c)** and **(d)** The same as **(a)** and **(b)** with X-ray contours overlaid. The solid contours in **(c)** and **(d)** are 3, 5, 10, 15, and 20-σ above the mean local background. The dashed contours are 50, 100, 150, and 200-σ above the mean local background.

Fig. 9.— **(a)** Curtis-Schmidt Hα PDS scan of LMC 6 (Courtesy R. Kennicutt). **(b)** *ROSAT* PSPC image of LMC 6 in the R4 – R7 (0.44 – 2.04 keV) energy band. **(c)** and **(d)** The same as **(a)** and **(b)** with X-ray contours overlaid. The solid contours in **(c)** and **(d)** are 3, 5, 10, 15, and 20-σ above the mean local background. The dashed contours are 50, 100, 150, and 200-σ above the mean local background.

Fig. 10.— **(a)** Curtis Schmidt Hα PDS scan of LMC 10 (Courtesy R. Kennicutt). **(b)** *ROSAT* PSPC image of LMC 10 in the R4 – R7 (0.44 – 2.04 keV) energy band. **(c)** and **(d)** The same as **(a)** and **(b)** with X-ray contours overlaid. The solid contours in **(c)** and **(d)** are 3, 5, 10, 15, and 20-σ above the mean local background. The dashed contours are 50, 100, 150, and 200-σ above the mean local background.

Fig. 11.— **(a)** Curtis Schmidt Hα PDS scan of the LMC Spur (Courtesy R. Kennicutt). **(b)** *ROSAT* PSPC image of the LMC Spur in the R4 – R7 (0.44 – 2.04 keV) energy band. **(c)** and **(d)** The same as **(a)** and **(b)** with X-ray contours overlaid. The solid contours in **(c)** and **(d)** are 3, 5, 10, 15, and 20-σ above the mean local background. The dashed contours are 50, 100, 150, and 200-σ above the mean local background.

Fig. 12.— **(a)** Hα Sky Survey image of the LMC Bar (Gaustad et al. 1999). **(b)** *ROSAT* PSPC image of the LMC Bar in the R4 – R7 (0.44 – 2.04 keV) energy band. **(c)** and **(d)** The same as **(a)** and **(b)** with X-ray contours overlaid. The solid contours in **(c)** and **(d)** are 3, 5, 10, 15, and 20-σ above the mean local background. The dashed contours are 50, 100, 150, and 200-σ above the mean local background.

Fig. 13.— Plot of *ROSAT* PSPC count ratios of the R6 + R7 (0.73 – 2.04 keV) energy band to the R4 + R5 (0.44 – 1.21 keV) energy band for the individual objects versus foreground absorption column. The nearly horizontal lines are lines of constant temperature for a 40% solar abundance Raymond & Smith (1977) thermal plasma. They correspond to a thin, thermal plasma with temperatures ranging from Log $(\frac{\mathrm{T}}{\mathrm{K}}) = 6.1$ to Log $(\frac{\mathrm{T}}{\mathrm{K}}) = 6.9$ with an increment of 0.2 dex. The PSPC $\frac{(\mathrm{R6+R7})}{(\mathrm{R4+R5})}$ count ratios for each object are plotted at the mid-point between the lower and upper limits on the foreground absorption column. The vertical error bars show the errors on the count ratio. The horizontal error bars show the range of the assumed foreground absorption for each object.

Table 1. PSPC Observations Included in the Mosaic.

Sequence No.	Sets[a]	α (J2000)	δ (J2000)	Exposure (sec)	Target Name
400161	1	4 40 0.0	-68 10 12.0	2567.0	RX J0440-6810
500263	1	4 55 21.6	-67 09 0.0	12273.7	N9
500258	1	4 55 43.2	-68 39 0.0	12379.1	N 86
900320	2	4 56 33.6	-66 28 48.0	30435.4	N11
600098	1	5 00 4.8	-66 25 48.0	10285.5	REGION C
600577	1	5 00 4.8	-66 25 48.0	8792.9	REGION C
500060	1	5 05 43.2	-67 52 47.5	3821.8	SNR 0505-67.9
300129	1	5 08 0.0	-68 37 47.5	3936.2	NOVA LMC 1988 NO. 2
500037	1	5 09 0.0	-68 43 48.0	6667.0	N 103B
500063	1	5 09 31.2	-67 31 11.5	8496.8	SNR 0509-67.5
180033	1	5 13 52.8	-69 51 0.0	2472.0	TOO RX J0513.9-6951
500052	2	5 13 55.2	-67 20 23.5	10767.6	DEM105
900398	3	5 13 55.2	-69 52 12.0	12005.6	RX J0513.9-6951
500061	1	5 19 33.6	-69 02 24.0	3706.4	SNR 0519-69.0
400263	2	5 20 28.8	-71 57 36.0	21783.9	LMCX-2
500053	1	5 20 48.0	-65 28 12.0	8120.0	DEM137
110109	1	5 21 28.5	-70 35 42.0	432.6	XRT/PSPC SPEC/FLUX N132D
500093	1	5 22 2.4	-67 55 12.0	8493.7	N44
400154	1	5 22 26.4	-67 58 12.0	6375.3	N44C/STAR 2
300126	1	5 23 50.4	-70 00 36.0	7420.4	NOVA LMC 87
141507	1	5 25 0.0	-69 38 24.0	1296.7	XRT/PSPC SPEC/FLUX N132D
141508	1	5 25 0.0	-69 38 24.0	1106.1	XRT/PSPC SPEC/FLUX N132D
141519	1	5 25 0.0	-69 38 24.0	1074.3	XRT/PSPC SPEC/FLUX N132D
141542	1	5 25 0.0	-69 38 24.0	1627.3	XRT/PSPC SPEC/FLUX N132D
141543	1	5 25 0.0	-69 38 24.0	1464.0	XRT/PSPC SPEC/FLUX N132D
141800	1	5 25 0.0	-69 38 24.0	1010.1	XRT/PSPC SPEC/FLUX N132D
141937	1	5 25 0.0	-69 38 24.0	1880.4	XRT/PSPC SPEC/FLUX N132D
142011	1	5 25 0.0	-69 38 24.0	2526.6	XRT/SPEC/FLUX N132D
500141	2	5 25 2.4	-69 38 24.0	11101.7	N 132 D
500062	1	5 25 28.8	-65 59 24.0	5723.5	SNR 0525-66.0

Table 1—Continued

Sequence No.	Sets[a]	α (J2000)	δ (J2000)	Exposure (sec)	Target Name
500054	2	5 25 52.8	-67 30 0.0	7302.3	DEM192
600099	1	5 26 24.0	-66 13 48.0	8580.8	REGION E
600578	1	5 26 24.0	-66 13 48.0	10228.3	REGION E
500138	3	5 26 36.0	-68 50 23.5	30604.4	N144
400148	1	5 27 48.0	-69 54 0.0	5967.1	RX J0527.8-6954
400298	3	5 27 48.0	-69 54 0.0	15875.0	RX J0527.8-6954
201249	1	5 27 50.4	-65 56 24.0	1363.1	HD 36705
201258	1	5 27 57.6	-65 57 0.0	1799.7	HD 36705
201592	1	5 27 57.6	-65 57 0.0	3384.9	HD 36705
900542	1	5 28 40.8	-66 48 35.5	965.2	LMC4, POINTING 13
180027	1	5 28 43.2	-65 27 0.0	2520.0	TOO ORFEUS AB DOR
201588	1	5 28 43.2	-65 27 0.0	2052.4	HD 36705
200138	1	5 28 45.6	-65 27 0.0	1495.0	HD 36705
200873	1	5 28 45.6	-65 27 0.0	1177.9	HD 36705
200874	2	5 28 45.6	-65 27 0.0	2126.5	HD 36705
200875	1	5 28 45.6	-65 27 0.0	1162.0	HD 36705
200877	1	5 28 45.6	-65 27 0.0	1568.8	HD 36705
900541	1	5 29 4.8	-66 56 24.0	983.3	LMC4, POINTING 12
900540	1	5 29 31.2	-66 42 0.0	973.7	LMC4, POINTING 11
201591	1	5 29 33.6	-65 57 0.0	1421.8	HD 36705
900543	1	5 29 57.6	-66 49 48.0	1028.8	LMC4, POINTING 14
200692	1	5 30 45.6	-65 54 36.0	34813.7	LMC X-4 AND AB DOR
900544	1	5 30 48.0	-66 43 12.0	2069.6	LMC4, POINTING 15
201589	1	5 30 55.2	-65 54 0.0	1199.3	HD 36705
201248	1	5 31 2.4	-65 54 0.0	1193.0	HD 36705
900553	1	5 31 12.0	-66 51 36.0	1182.0	LMC4, POINTING 24
110173	1	5 31 14.4	-69 34 12.0	1767.9	XRT/PSPC PSF LMC X-1
201254	1	5 31 24.0	-65 52 12.0	1352.6	HD 36705
900539	1	5 31 36.0	-66 59 24.0	1342.7	LMC4, POINTING 10
201250	1	5 31 48.0	-65 50 23.5	3327.3	HD 36705

Table 1—Continued

Sequence No.	Sets[a]	α (J2000)	δ (J2000)	Exposure (sec)	Target Name
900538	1	5 32 2.4	-66 44 24.0	1342.6	LMC4, POINTING 09
110176	1	5 32 12.0	-70 08 24.0	1547.8	XRT/PSPC PSF LMC X-1
140636	1	5 32 16.8	-63 54 36.0	1561.7	XRT/PSPC BORE WOB LMC X-3
300172	3	5 32 28.8	-70 21 36.0	12737.8	NOVA LMC 88 #1
400246	1	5 32 50.4	-66 22 12.0	13986.7	4U 0532-664
201253	1	5 32 52.8	-65 43 12.0	2056.4	HD 36705
900547	2	5 32 52.8	-67 00 36.0	1368.3	LMC4, POINTING 18
201256	1	5 33 0.0	-65 42 0.0	1315.0	HD 36705
900546	2	5 33 16.8	-66 45 36.0	1034.4	LMC4, POINTING 17
900536	1	5 34 33.6	-66 46 48.0	983.0	LMC4, POINTING 07
900552	1	5 34 57.6	-66 55 12.0	2037.9	LMC4, POINTING 23
160068	1	5 35 9.6	-64 42 36.0	1400.2	XRT/PSPC BORE NOWOB
900549	1	5 35 24.0	-67 03 0.0	1296.6	LMC4, POINTING 20
500100	2	5 35 28.8	-69 16 11.5	25669.7	SN1987A
500140	3	5 35 28.8	-69 16 11.5	24250.7	SN1987A
500303	1	5 35 28.8	-69 16 11.5	9157.4	SN 1987 A
600100	2	5 35 38.4	-69 16 11.5	18897.8	REGION F
900548	1	5 35 50.4	-66 48 0.0	1045.5	LMC4, POINTING 19
300335	1	5 36 12.0	-70 45 0.0	9904.3	2 NEW SUPERSOFT SRCS
900535	1	5 36 38.4	-67 04 12.0	837.2	LMC4, POINTING 06
140007	1	5 36 40.8	-64 05 23.5	1015.1	XRT/PSPC BORE NOWOB LMC X-3
140637	1	5 36 40.8	-64 05 23.5	1768.7	XRT/PSPC BORE WOB LMC X-3
110175	1	5 36 52.8	-69 49 12.0	1686.2	XRT/PSPC PSF LMC X-1
110174	1	5 37 4.8	-69 37 47.5	2500.3	XRT/PSPC PSF LMC X-1
110168	1	5 37 7.2	-69 01 48.0	1794.0	XRT/PSPC PSF LMC X-1
141806	1	5 37 9.6	-64 22 47.5	1202.8	XRT/PSPC LMC X-3 BORE
140005	1	5 37 24.0	-64 49 12.0	1215.4	XRT/PSPC BORE NOWOB LMC X-3
140635	1	5 37 24.0	-64 49 12.0	1148.2	XRT/PSPC BORE WOB LMC X-3
900551	1	5 37 52.8	-67 05 23.5	961.0	LMC4, POINTING 22
110167	1	5 38 30.0	-69 31 19.0	2200.4	XRT/PSPC PSF LMC X-1

Table 1—Continued

Sequence No.	Sets[a]	α (J2000)	δ (J2000)	Exposure (sec)	Target Name
500131	1	5 38 33.6	-69 06 36.0	15449.0	N157
900532	1	5 38 45.6	-66 58 12.0	1147.2	LMC4, POINTING 03
130001	1	5 38 55.2	-64 04 48.0	1364.7	XRT/PSPC BORE NOWOB LMC X-3
130002	1	5 38 55.2	-64 04 48.0	1675.6	XRT/PSPC BORE WOB LMC X-3
141805	1	5 38 57.6	-64 04 48.0	996.6	XRT/PSPC LMC X-3 BORE
400078	1	5 38 57.6	-64 04 48.0	7220.3	LMC X-3
110182	1	5 39 0.0	-69 59 24.0	1772.2	XRT/PSPC PSF LMC X-1
140632	1	5 39 4.8	-63 50 24.0	1400.4	XRT/PSPC BORE WOB LMC X-3
900533	1	5 39 9.6	-67 06 36.0	1534.9	LMC4, POINTING 04
140004	1	5 39 24.0	-64 19 48.0	1378.5	XRT/PSPC BORE NOWOB LMC X-3
140634	1	5 39 24.0	-64 19 48.0	1640.1	XRT/PSPC BORE WOB LMC X-3
120006	1	5 39 38.4	-69 44 24.0	1301.3	XRT/PSPC LMC X-1
120101	1	5 39 38.4	-69 44 24.0	1539.4	XRT/PSPC LMC X-1
400079	2	5 39 38.4	-69 44 24.0	5470.0	LMC X-1
140631	1	5 39 48.0	-63 20 24.0	1482.3	XRT/PSPC BORE WOB LMC X-3
150044	1	5 40 12.0	-69 19 48.0	5151.6	PSR 0540-69
400052	1	5 40 12.0	-69 19 48.0	6547.2	PSR 0540-69
400133	1	5 40 12.0	-69 19 48.0	1722.0	PSR 0540-69
110179	1	5 40 43.2	-69 30 36.0	1731.9	XRT/PSPC PSF LMC X-1
110170	1	5 41 0.0	-69 57 36.0	2088.2	XRT/PSPC PSF LMC X-1
140008	1	5 41 12.0	-64 04 12.0	1266.9	XRT/PSPC BORE NOWOB LMC X-3
140638	1	5 41 12.0	-64 04 12.0	1425.9	XRT/PSPC BORE WOB LMC X-3
141807	1	5 41 19.2	-63 51 0.0	1131.9	XRT/PSPC LMC X-3 BORE
160071	1	5 41 36.0	-63 23 24.0	1444.9	XRT/PSPC BORE NOWOB
110180	1	5 42 8.6	-69 01 55.0	1270.6	XRT/PSPC PSF LMC X-1
110178	1	5 42 16.8	-69 39 0.0	1937.7	XRT/PSPC PSF LMC X-1
110171	1	5 42 19.2	-69 50 23.5	1999.5	XRT/PSPC PSF LMC X-1
110169	1	5 44 26.4	-70 22 12.0	1846.1	XRT/PSPC PSF LMC X-1
141851	1	5 44 48.0	-65 43 48.0	4447.3	XRT/PSPC UV LEAK, DELTA DOR
140009	1	5 45 36.0	-63 54 36.0	1472.4	XRT/PSPC BORE NOWOB LMC X-3

Table 1—Continued

Sequence No.	Sets[a]	α (J2000)	δ (J2000)	Exposure (sec)	Target Name
140639	1	5 45 36.0	-63 54 36.0	1584.0	XRT/PSPC BORE WOB LMC X-3
400012	1	5 46 45.6	-71 09 0.0	15496.1	CAL87
400013	1	5 46 45.6	-71 09 0.0	14298.1	CAL87
500259	1	5 47 9.6	-69 42 0.0	3918.0	DEM 316
110177	1	5 48 9.6	-69 37 47.5	1900.3	XRT/PSPC PSF LMC X-1
201610	1	5 50 0.0	-71 52 12.0	7668.1	RX J0549.9-7151
100406	1	6 00 0.0	-66 33 35.5	18345.2	WFC BACKGROUND SEP S1
900175	1	6 00 0.0	-70 40 12.0	5907.2	LMC FRONT
900174	1	6 10 0.0	-71 30 0.0	5896.0	LMC FRONT

Note. — Units of right ascension are hours, minutes, and seconds, and units of declination are degrees, arcminutes, and arcseconds.

[a]Number of separate data sets processed for observation.

Table 2. Broad Energy Band Definitions.

Band Name	PI Channels	Energy[a] (keV)
R1	8 − 19	0.11 − 0.284
R2	20 − 41	0.14 − 0.284
R4	52 − 69	0.44 − 1.01
R5	70 − 90	0.56 − 1.21
R6	91 − 131	0.73 − 1.56
R7	132 − 201	1.05 − 2.04

[a]10% of peak response.

Table 3. Relevant Parameters of the X-ray Mosaics.

Band	Average Exposure (ksec)	Total Counts Observed	Total Counts Background	Average Intensity[ab]
R1	20.77	1223488	258289	252
R2	21.15	1887260	338936	397
R4	20.33	1314914	228274	290
R5	20.25	1884291	108108	475
R6	19.69	2478833	129499	646
R7	16.92	1307574	109995	383

[a]Units of 10^{-6} counts s^{-1} $arcmin^{-2}$.

[b]The area covered by the PSPC mosaics is 51.3 $degree^2$.

Table 4. Large Scale Diffuse X-ray Emission Regions

Object	α^{a} (J2000)	δ^{a} (J2000)	Dimension[a] (pc)	$N_{\rm H\,I}^{{\rm Gal},b}$ (10^{21} cm^{-2})	$N_{\rm H\,I}^{{\rm LMC},c}$ (10^{21} cm^{-2})
LMC 1	05 00 11	−65 35 41	700	0.39	1.09
LMC 2	05 41 36	−69 28 40	900	0.67	3.70
LMC 3	05 29 38	−69 17 48	1000	0.62	1.54
LMC 4	05 30 59	−66 47 53	1400 × 1000	0.58	0.68
LMC 5	05 22 05	−66 07 15	800	0.52	1.19
LMC 6	04 57 48	−68 40 32	600	0.70	1.25
LMC 10 (DEM L 268)	05 37 01	−68 25 20	1000 × 600	0.62	1.94
LMC Spur	05 43 15	−70 07 46	900 × 500	0.70	3.06
LMC Bar	05 22 30	−69 26 17	2700 × 900	0.63	1.19

Note. — Units of right ascension are hours, minutes, and seconds, and units of declination are degrees, arcminutes, and arcseconds.

[a]The coordinates and physical sizes have been taken from Meaburn (1980) for LMC 1 – LMC 6, Davies, Elliot, & Meaburn (1976) for LMC 10, and measured from Figure 1 for the LMC Spur and the LMC Bar.

[b]From Dickey & Lockman (1990).

[c]From Rohlfs et al. (1984).

Table 5. PSPC Count Rates of the Large Scale Diffuse Emission Regions

Object	Region Size[a] (arcmin^2)	R4 + R5 (counts s^{-1})	R6 + R7 (counts s^{-1})	$\frac{(R6+R7)}{(R4+R5)}$
LMC 1	954	0.018 ± 0.015	0.006 ± 0.0004	0.324 ± 0.281
LMC 2	1879	1.201 ± 0.382	1.239 ± 0.359	1.032 ± 0.444
LMC 3	2459	0.918 ± 0.248	0.584 ± 0.266	0.637 ± 0.337
LMC 4	5144	0.499 ± 0.964	0.262 ± 0.753	0.525 ± 1.817
LMC 5	883	0.072 ± 0.183	0.066 ± 0.099	0.914 ± 2.697
LMC 6	825	0.016 ± 0.002	0.004 ± 0.009	0.241 ± 0.533
LMC 10 (DEM L 268)	1414	0.589 ± 0.400	0.301 ± 0.358	0.510 ± 0.700
LMC Spur	1347	0.841 ± 0.373	0.622 ± 0.309	0.739 ± 0.492
LMC Bar	5403	1.318 ± 1.474	0.846 ± 1.022	0.641 ± 1.057

[a]Angular size of the region from which the source counts were extracted.

Table 6. Physical Conditions of the Hot Gas

Object	l (pc)	$kT^{\rm a}$ (keV)	$F_X^{\rm a,b}$ (10^{-11} erg cm^{-2} s^{-1})	$L_X^{\rm a,b,c}$ (10^{36} erg s^{-1})	$\Lambda^{\rm b}$ (10^{-24} erg cm^3 s^{-1}
LMC 1	400	0.19 – 0.21	0.07 – 0.10	0.21 – 0.30	6.00 – 7.14
LMC 2	500	0.43 – 0.49	10.0 – 13.15	29.91 – 39.34	12.61 – 13.57
LMC 3	600	0.32 – 0.36	3.6 – 4.87	10.77 – 14.58	9.91 – 10.86
LMC 4	1060	0.29 – 0.33	1.40 – 1.93	4.19 – 5.77	9.47 – 10.35
LMC 5	400	0.54 – 0.60	0.23 – 0.28	0.69 – 0.83	14.49 – 14.53
LMC 6	440	0.15 – 0.16	0.13 – 0.20	0.39 – 0.61	3.82 – 3.84
LMC 10 (DEM L 268)	480	0.24 – 0.26	3.5 – 4.69	10.47 – 14.03	7.89 – 8.68
LMC Spur	460	0.29 – 0.33	6.8 – 9.77	20.34 – 29.24	9.47 – 10.35
LMC Bar	775	0.34 – 0.39	4.4 – 5.45	13.16 – 16.30	10.35 – 11.41

Note. — The range in values for the derived physical conditions of the hot gas correspond to the lower ar absorption discussed in §4.1. The lower limit of the foreground absorption column, $N_{HI}^{Gal} + N_{HI}^{LMC}$, corres and Λ and the lower limits on F_X, L_X, and n_e. The upper limit of the foreground absorption column, $2N$ lower limits on kT and Λ and the upper limits on F_X, L_X, and n_e.

[a]Measured for a Raymond-Smith (1977) thermal plasma with 40% solar abundance.

[b]Measured in the PSPC R4 to R7 energy band (0.44 – 2.04 keV).

[c]Assuming a distance of 50 kpc to the LMC.

[d]Derived using an assumed path length of l and the angular size given in Table 5.

Table 7. X-ray Emission in the PSPC Mosaic

Source	Count Rate (counts s^{-1})	Percentage[a]
Foreground & Background Sources Projected Toward the LMC		
AGN & Background Galaxies	0.8[b]	
Foreground Stars	11.3[b]	
Unclassified Point Sources[c]	7.6[b]	
LMC Sources		
X-ray Binaries & Supersoft Sources	53.6[b]	41%
SNRs	26.9[b]	21%
Superbubbles[d]	2.6[e]	2%
Supergiant Shells[f]	8.2[e]	6%
Diffuse Gas in the Field		
LMC Spur & LMC Bar	3.4[e]	3%
Anonymous Sources	34.7[e]	27%
Total X-ray emission from the LMC	129.4	100%

[a]Percentages are only calculated for sources that are known to be LMC sources.

[b]From Haberl & Pietsch (1999).

[c]These objects may be associated with the LMC.

[d]This includes emission from 30 Doradus.

[e]Measured in the 0.1 – 2.4 keV energy band.

[f]LMC 1 – LMC 6, and LMC 10.